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SPECIFICATION

CERAMIC HEATER AND METHOD OF PRODUCING THE SAME AND ELECTRICALLY CONDUCTIVE PASTE FOR HEATING BODY

TECHNICAL FIELD

Sub B1

This invention relates to a ceramic heater used for drying in a semiconductor industry, and more particularly to a ceramic heater facilitating temperature control and being thin and light and a method of producing the same as well as an electrically conductive paste used for the formation of a heating element of the heater.

BACKGROUND ART

Sub B2

Typical semiconductor products are manufactured by applying an etching resist onto a silicon wafer and then etching it. In this case, a photosensitive resin applied onto the surface of the silicon wafer should be dried after the application. As a drying method, it is general to place the silicon wafer coated with the resin on a heater and then conduct the heating.

As such a heater, it has typically been used to attach a heating body to a back surface of an aluminum substrate. However, such a metallic heater has problems as mentioned below.

That is, th substrat of the h ater itself is a m tal, so that the thickn ss of the substrate

should b made to about 15 mm. Because, strain is caused in the thin metal plate due to thermal expansion resulted from the heating and hence the wafer placed on the metal plate is broken or tilted. Therefore, the conventional metal heater has problems that the weight is heavy and the volume is bulky.

And also, the heating of the silicon wafer by the heater is carried out by adjusting voltage and current applied to the heating body to control the temperature of the substrate. However, this method has a problem that since the metal plate is thick, the temperature of the heater substrate does not rapidly follow to the change of the voltage or current and the temperature control property is bad.

A primary object of the invention is to provide a heater easily conducting the temperature control and being thin and light as well as a method of producing the same.

Another object of the invention is to provide an electrically conductive paste for a heating body having excellent heat generating properties.

DISCLOSURE OF THE INVENTION

Sub B3

As a result of examinations on the above problem included in the conventional technique, the inventors noticed that a ceramic material having an exc ll nt h at conductivity, particularly nitrid c ramic or carbide c ramic is used as a substrat

for a h at r instead of th metal such as aluminum or th like. There is found out a discovery that such a ceramic substrate does not cause warping or strain even when it is made thin and can rapidly and easily conduct the temperature control and particularly it is excellent in the responsibility when the temperature control is carried out by changing a voltage or current applied to the heating body.

And also, the inventors have found that an electrically conductive paste containing metal particles has generally a property of hardly adhering to the nitride ceramic or carbide ceramic, but when a metal oxide is added to the electrically conductive paste, the adhesion property is improved through the sintering of the metal particles.

Under the above knowledge, the invention has been developed and the construction thereof is as follows:

1. The invention is a ceramic heater comprising a ceramic substrate made of a nitride ceramic or a carbide ceramic and a heating body arranged on a surface thereof.

2. The heating body is preferably arranged so as to embed a part thereof in the ceramic substrate.

3. The heating body is favorable to be made of a sintered body of m tal particles.

4. The heating body is favorable to b made

of the m tal particles and at least one m tal oxid selected from th group consisting of lead oxide, zinc oxide, silicon oxide, boron oxide, aluminum oxide, yttrium oxide and titanium oxide.

5. As the metal particles, it is favorable to use one or more of noble metal, lead, tungsten, molybdenum and nickel.

6. The heating body is favorable to be covered on its surface with a non-oxidizing metal layer.

7. The heating body is favorable to have a sectional shape that an aspect ratio at section (width of heating body/thickness of heating body) is 10~10000.

8. It is characterized in that a flat heating body having an aspect ratio at section (width of heating body/thickness of heating body) of 10~10000 is arranged in an inside of a ceramic substrate made of the nitride ceramic or carbide ceramic.

9. The invention is a ceramic heater comprising a ceramic substrate made of a nitride ceramic or a carbide ceramic and a flat heating body arranged in an inside thereof, wherein an arranging position of the heating body is a position eccentrically arranged from a center of the substrate in a thickness direction thereof and a face far apart from the h ating body is a h ating face. This h ater is also favorable to hav

f atur s of the abov items 2~8.

10. The heating body is favorable to b mad of a sintered body of metal particles or electrically conductive ceramic.

11. The heating body is favorable to be tungsten, molybdenum, tungsten carbide or molybdenum carbide.

12. The eccentric degree of the heating body is favorable to be a position from the heating face of the substrate to more than 50% but less than 100%.

13. The heating body is favorable to have an aspect ratio at section (width of heating body/thickness of heating body) of 10~10000.

14. The invention also proposes a method of producing a ceramic heater which comprises at least following steps ①~③.

① step of sintering nitride ceramic powder or carbide ceramic powder to form a substrate made of nitride ceramic or carbide ceramic;

② step of printing an electrically conductive paste on the substrate; and

③ step of sintering the electrically conductive paste by heating to form a heating body on the surface of the ceramic substrate.

15. It is preferable to adopt a step of plating a non-oxidizing metal onto the surface of the resulting heating body to form a metal coating lay r as a post step of th st p ③.

16. It is pr ferabl to us a mixed paste of

metal particles and m tal oxide as the electrically conductiv paste us d in th st p ②.

17. Furthermore, the invention proposes a method of producing a ceramic heater which comprises at least following steps ①~④.

① step of shaping nitride ceramic powder or carbide ceramic powder to form a green sheet made of nitride ceramic or carbide ceramic;

② step of printing an electrically conductive paste of metal particles alone or a mixture with a metal oxide thereof on the surface of the green sheet made of the nitride ceramic or carbide ceramic;

③ step of laminating the green sheet printed with the electrically conductive paste on one or more of another green sheet obtained by the same treatment as in the step ①; and

④ step of sintering the green sheets and the electrically conductive paste by heating under pressure.

18. It is favorable that when the green sheets obtained by the same treatment as in the step ① are laminated on the upper side and lower side of the green sheet printed with the electrically conductive paste in the step ②, the number ratio of the upper and lower green sheets is adjusted to 1/1 to 1/99.

19. Moreover, the invention proposes an el ctrically conductive past for a heating body of a c ramic heat r comprising m tal particl s and a

metal oxide.

20. As the metal particl s, it is favorable to use one or more of noble metal, lead, tungsten, molybdenum and nickel.

21. As the metal oxide, it is favorable to use one or more of lead oxide, zinc oxide, silicon oxide, boron oxide, aluminum oxide, yttrium oxide and titanium oxide.

22. As the electrically conductive paste, it is favorable to use a paste formed by mixing more than 0.1 wt% but less than 10 wt% of the metal oxide with the metal particles.

23. The metal particle is favorable to have an average particle size of 0.1~100 μm.

24. The metal particles are favorable to be flake-shaped particle or a mixture of spherical particle and flake-shaped particle.

Sub B4

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of a ceramic heater according to the invention;

Fig. 2 is a section view illustrating a use state of a ceramic heater according to the invention;

Fig. 3 is a diagrammatic view illustrating a production method of a ceramic heater according to the invention;

Fig. 4 is a diagrammatic view illustrating a state of conn cting a t rminal pin to a hole for

through-hole;

A Fig. 5a - 5d are diagrammatic views ~~Fig. 5 is a diagrammatic view~~ illustrating another production method of a ceramic heater according to the invention; and

A Figs. 6a and 6b are diagrammatic views ~~Fig. 6 is a diagrammatic view~~ illustrating the other production method of a ceramic heater according to the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Sub B5 The ceramic heater according to the invention is a heater wherein a ceramic substrate made of an insulative nitride ceramic or carbide ceramic is used and a heating body is formed on one surface of the ceramic substrate by printing and the other surface thereof is used as a heating face heating a semiconductor product such as silicon wafer or the like placed thereon.

In the ceramic heater according to the invention, a heating body having a flat sectional shape may be disposed in an inside of the ceramic substrate (sandwiched therebetween), wherein the heating body is eccentrically arranged from a center in a thickness direction of the substrate and a face apart away from the heating body is used as a heating face.

The nitride ceramic or carbide ceramic constituting the substrate is small in the thermal xpansion coefficient as compared with the metal and has a prop rty that warping or distortion is not

caus d by h ating even wh n it is made thin. Ther for , th substrate for the heater can be made thin and light.

And also, such a ceramic substrate is high in the thermal conductivity and thin, so that the surface temperature of the substrate rapidly follows to the temperature change of the heating body. That is, when the temperature of the heating body is changed by varying the voltage or current, the surface temperature of the ceramic substrate is changed while rapidly following to such a change.

In the ceramic heater according to the invention, a side of the substrate opposite to the side facing the heating body is a heating face, or a side of the substrate apart away from the heating body eccentrically arranged from the center of the substrate in the thickness direction is a heating face, so that the propagation of heat is uniformly and rapidly diffused over a whole of the substrate, whereby the occurrence of temperature distribution in the heating face restricted by the pattern of the heating body can be controlled and hence the distribution of the heating temperature can be made uniform.

In this connection, USP 5,643,483 discloses a technique that one surface of a quartz substrate is roughened and coated with a platinum-palladium paste to form a h ating body and a waf r is plac d on a surface of th substrat opposite to the heating

body for h ating. And also, USP 5,668,524 disclos s a ceramic heater provided with a chuck embedding a heater therein. Further, USP 5,566,043 discloses a heater formed by placing a heating body of a thermally decomposed graphite on a surface of a boron nitride substrate.

In USP 5,643,483, however, a quartz substrate is used and the heating body is made from a platinum-palladium paste, but the oxide as defined in the invention is not mixed with the paste, so that the heating body can not be formed unless the substrate is roughened.

In USP 5,668,524, the heating body is not eccentrically arranged and also concrete shape such as aspect ratio or the like is not disclosed. Therefore, the uniformity of temperature on the heating face is poor.

In USP 5,566,043, the heating body of thermally decomposed graphite is used, so that when it is heated in air above 500°C, the heating body itself is burnt out and hence the range of service temperature is restricted.

Thus, the invention is entirely different from the above conventional techniques.

In the invention, the ceramic substrate is favorable to have a thickness of about 0.5~5 mm. Because, when the thickness is too thin, the substrate is apt to be brok n.

As th nitride ceramic b ing a mat rial of

th c ramic substrat , it is desirabl to use at l ast one metal nitride ceramic selected from the group consisting of aluminum nitride, silicon nitride, titanium nitride and the like. On the other hand, as the carbide ceramic, it is desirable to use at least one metal carbide ceramic selected from the group consisting of silicon carbide, zirconium carbide, titanium carbide, tungsten carbide and the like. Among these ceramics, aluminum nitride is preferable. Because thermal conductivity of aluminum nitride is as highest as 180 W/m.K.

Further, the heating body arranged on the ceramic substrate is formed by sintering metal particles or metal oxide particles in the electrically conductive paste. These particles can be baked on the surface of the ceramic substrate by sintering under heating. Moreover, the sintering treatment is carried out to an extent that the metal particles or the metal particle and ceramic are fused to each other.

Then, the heating body 2 is preferably a concentrically shaped pattern as shown in Fig. 1 because it is required to uniformly raise the temperature of the ceramic substrate 1 as a whole. The patterned heating body 2 is desirable to have a thickness of about 1~50 μm, and when the heating body 2 is formed on th surfac of the substrate 1, th thickn ss is favorabl to b 1~10 μm. On th

other hand, when the heating body is form d in the inside of the substrate 1, the thickness is favorable to be 1~50 μm.

And also, the heating body is desirable to have a width of about 0.1~20 mm, but when the heating body 2 is formed on the surface of the substrate 1, the width is favorable to be 0.1~5 mm, and when the heating body 2 is formed in the inside of the substrate 1, the width is favorable to be 1~20 mm. The reason on these limitations is due to the fact that the resistance value can be changed by varying the thickness and width of the heating body 2 but the above ranges are most effective to the temperature control of the heating body. Moreover, the resistance value of the heating body 2 becomes larger as the body becomes thin and fine.

Furthermore, the thickness and width can be made large when the heating body 2 is formed in the inside of the substrate 1. Because, when the heating body 2 is arranged in the inside, a distance between the heating face and the heating body becomes short and the temperature uniformity of the heating face of the ceramic substrate 1 lowers, so that in order to uniformly heat the heating face, it is required to widen the width of the heating body 2 itself. On the other hand, when the heating body is arranged in the inside, it is needless to consider the adh sion prop rty to the nitrid c ramic of the substrat or the like, so that a high melting point

metal such as tungst n, molybdenum or the like, and carbides of tungsten or molybdenum can be used and hence the resistance value can be increased. As a result, the thickness of the heating body can be thickened for preventing the breakage or the like.

The heating body is generally rectangular or ellipsoidal at its section, but it is desirable to be a flat shape. Particularly, when the heating body is arranged in the inside of the ceramic substrate 1, it is essential to be flat. Because, the flat sectional shape is easy to dissipate heat toward the heating face and hence the temperature distribution is hardly caused in the heating face.

The aspect ratio at the section of the heating body 2 (width of the heating body/thickness of the heating body) is desirably about 10~10000, preferably 50~5000. When the aspect ratio is adjusted to the above range, the resistance value of the heating body 2 can be increased and at the same time, the uniformity of the temperature distribution in the heating face can be ensured.

When the thickness of the patterned heating body 2 arranged on the surface of the ceramic substrate 1 or inside thereof is constant, if the aspect ratio is small, the transmission quantity of heat directing to the heating face of the substrate becomes small and the heating face has the same heat distribution as in the patt rned heating body. Inversely, if th asp ct ratio is too larg , th

t mp rature in a portion just abov the c nter of th patt rned heating body b comes higher and finally the same heat distribution as in the patterned heating body is formed in the heating face. Considering such a temperature distribution, the aspect ratio at the section of the heating body 2 (width of the heating body/thickness of the heating body) is desirable to be within a range of 10~10000.

This is due to the fact that when the aspect ratio of the heating body 2 is made to 50~5000, cracking or peeling due to thermal shock hardly occurs.

Moreover, when the heating body 2 is formed in the inside of the ceramic substrate 1, the aspect ratio can be made large. However, in case of forming the heating body 2 in the inside, the distance between the heating face and the heating body becomes short and the uniformity of the surface temperature lowers, so that the heating body itself is necessary to be flat shape.

In the invention, when the heating body 2 is arranged in the inside of the ceramic substrate 1, the arranging position of the heating body in the thickness direction can be made eccentric, but it is desirable that the eccentric degree is a position from a surface of the substrate (heating face) to more than 50% but less than 100% because the temp ratur distribution of the heating face is prev nt d and the occurr nc of warping in the

ceramic substrat can be controll d. It is pr ferably 55~95%.

And also, when the heating body 2 is formed in the inside of the ceramic substrate 1, the layer forming the heating body may be divided into plural stages. In this case, it is desirable that the patterns of the divided layers are formed so as to supplement with each others to thereby render into a state that complete pattern is formed in any layers viewed from the heating face. For example, there is a structure that the upper layer and the lower layer are arranged in a checkered pattern to form a complete pattern as a whole.

Further, when the heating body 2 is arranged on the surface of the ceramic substrate 1, it is desirable that a part of the heating body (bottom portion) is embedded in the ceramic substrate. Such an arrangement of the heating body can simultaneously realize the improvement in the resistance control of the heating body and the improvement in the adhesion property to the ceramic substrate.

There is described an electrically conductive paste used for the formation of the heating body on the ceramic substrate below. The electrically conductive paste is usual to be metal particle or electrically conductive ceramic ensuring electrical conductivity, or a mixtur with a resin, a solvent, a tackifi r and the like.

As th metal particl , us may be made of one or more selected from noble metal (gold, silv r, platinum, palladium), lead, tungsten, molybdenum and nickel. These metals are not relatively oxidized and show a sufficient resistance to heating. As the electrically conductive ceramic, use may be made of one or more selected from carbides of tungsten or molybdenum and so on.

These metal particles or electrically conductive ceramic are desirable to have a particle size of 0.1~100 μm. When the particle size is too small, the oxidation is easily caused, while when it is too large, the sintering is hardly conducted and the resistance value becomes large.

The metal particles can be used in a spherical shape, a flake-shape or a mixture of spherical shape and flake-shape. Particularly, when the shape is flake, a metal oxide mentioned below is easily held between the metal particles and the adhesion property between the heating body and the nitride ceramic or the like is improved.

As the resin used in the electrically conductive paste, epoxy resin, phenolic resin or the like is favorable. As the solvent, isopropyl alcohol or the like may be used. As the tackifier, cellulose or the like may be used.

And also, a metal oxide is further included in the electrically conductive past in addition to th m tal particles, which is effective to form a

sint r d mixtur body of the m tal particles and the m tal oxide as a h ating body. That is, when the metal oxide is interposed between the nitride ceramic or carbide ceramic and the metal particle, the adhesion property can be improved. Although the reason of improving the adhesion property is not clear, an oxide film is slightly existent on the surface of the metal particle or the surface of the nitride ceramic or carbide ceramic, so that it is guessed that the oxide film shows an affinity with the metal oxide and is easily united therewith and hence the metal particles adhere to the nitride ceramic or carbide ceramic through the oxide.

As the metal oxide, use may be made of one or more selected from lead oxide, zinc oxide, silicon oxide, boron oxide, aluminum oxide, yttrium oxide and titanium oxide. These oxides can improve the adhesion property between the metal particle and the nitride ceramic or carbide ceramic without increasing the resistance value of the heating body.

The addition amount of the metal oxide is desirable to be 0.1~less than 10 wt% to the metal particle. When the amount is less than 0.1 wt%, the addition effect is not obtained, while when it is not less than 10 wt%, the resistance value of the heating body 2 is too large.

Moreover, the mixing ratio of these metal oxides is d sirable to adjust so that wh n the total amount of th m tal oxides is 100 wt%, lead oxid is

1~10 wt%, silicon oxide is 1~30 wt%, boron oxid is 5~50 wt%, zinc oxide is 20~70 wt%, aluminum oxide is 1~10 wt%, yttrium oxide is 1~50 wt% and titanium oxide is 1~50 wt% and the total thereof does not exceed 100 wt%. These ranges are particularly effective to improve the adhesion property between the metal particle and the nitride ceramic.

Thus, when the addition amount of the metal oxide is adjusted to be within a range of 0.1~less than 10 wt% per the metal particle, the area resistance of the heating body can be made 1~45 mΩ/□. As the area resistance becomes too large, the amount of heat generation to an applied voltage is too large and the control is difficult in case of arranging the heating body on the surface of the ceramic substrate. Moreover, when the amount of the metal oxide is not less than 10 wt%, the area resistance exceeds 50 mΩ/□ and the amount of heat generation is too large and the temperature control is difficult and the uniformity of the temperature distribution in the heater lowers.

Although the resisting body for the heater has hitherto been considered to be unsuitable unless the area resistance is not less than 50 mΩ/□ (JP-A-4-300249), according to the invention, the area resistance is inversely made to not more than 45 mΩ/□ to facilitate the temperature control and ensure th uniformity of th t mperatur distribution.

As another mbodim nt of th invention, it is

d sirable to cov r th surfac of the heating body with a metal lay r. Since th h ating body is a sintered body of metal particles as mentioned above, when it is exposed in air, it is easily oxidized to change the resistance value. Now, the oxidation is prevented by covering the surface of the metal particle sintered body with the metal layer. The thickness of the metal layer is desirable to be about 0.1~10 μm. Because it is the range capable of preventing the oxidation of the heating body without changing the resistance value of the heating body.

The metal coated on the surface of the metal particle sintered body may be a non-oxidizing metal. For example, it may be one or more selected from gold, silver, palladium, platinum and nickel. Among them, nickel is favorable. Because, the heating body is generally required to have a terminal for connecting to a power source and the terminal is attached to the heating body through a solder, but nickel has an action of preventing the thermal diffusion of the solder. As a connection terminal, there can be used a terminal pin made of Kovar.

However, when the heating body is arranged in the inside of the ceramic substrate, the surface of the heating body is not oxidized, so that the covering is useless.

As the solder, use may be made of solder alloys such as silv r-lead, l ad-bismuth, bismuth-tin and th lik . Th thickn ss of th sold r lay r

is suffici ntly within a rang of 0.1~50 μm for ensuring th conn ction through th solder.

In the invention, as shown in Fig. 5(d), a thermocouple 61 may be embedded in the ceramic substrate 1, if necessary. The thermocouple 61 measures a temperature of the ceramic substrate 1 and adjusts voltage and current based on the measured data, whereby the temperature of the heating face of the ceramic substrate 1 can be controlled easily and accurately.

Fig. 2 is a partial section view illustrating a use state of the ceramic heater according to the invention. Numeral 3 is a terminal pin, numeral 4 a metal (Ag-Pb) particle sintered body, numeral 5 a metal (Ni) covering layer. and a heating body 2 is constituted with 4 and 5. And also, numeral 6 is a solder layer, and the terminal pin is attached through the solder layer.

Furthermore, a plurality of through-holes 8 are formed in the ceramic substrate 1, and a support pin 7 for a semiconductor wafer is inserted into the through-hole 8, and a semiconductor wafer 9 is attached to a top of the pin 7 protruding onto the ceramic substrate 1 adjacent thereto or at a slight space. In this case, the semiconductor wafer 9 is delivered onto a transferring machine (not shown) or the semiconductor wafer 9 is received from the transferring machine by lifting up and down the support pin 7.

The production method of the ceramic heater according to the invention will b described below.

A. In case of forming the heating body on the surface of the ceramic substrate (Fig. 2)

(1) Step of sintering powder of insulative nitride ceramic or insulative carbide ceramic to form a plate-shaped body of nitride ceramic or carbide ceramic (ceramic substrate).

In this step, powder of nitride ceramic such as aluminum nitride and the like or carbide ceramic such as silicon carbide and the like, or a mixed powder with a sintering aid such as yttria or the like and a binder, if necessary, is rendered into granules by a method such as spray-drying method or the like and the resulting granules are placed in a mold or the like and shaped into a plate by pressing to form a green shaped body.

If necessary, a through-hole 8 for inserting a support pin 7 for semiconductor wafer and a recess portion 62 embedding a thermocouple 61 therein are formed in the green shaped body.

Then, the green shaped body is sintered by heating and firing to produce a ceramic plate-shaped body. In the heating and firing, a ceramic substrate for heater having no pore is produced by pressing. The heating and firing may be conducted above a sintering temperature, but 1000~2500°C is favorable in th nitrid ceramic or carbid c ramic.

(2) Step of printing an l ctrically

conductiv past containing metal particles on th surface of th ceramic plate-shaped body obtained in the step (1) (heater plate or ceramic substrate) to form a metal particle layer 4.

In this step, the electrically conductive paste comprised of metal particles, resin and solvent and having a high viscous fluidity is printed at a given position by a method such as screen printing or the like. The reason why the electrically conductive paste is applied by printing to form the metal particle layer 4 is due to the fact that it is desirable to accurately form a pattern of concentric circles as shown in Fig. 1 for the formation of a heating body 2 for heating a whole of the ceramic substrate at a uniform temperature.

And also, the sectional shape of the heating body is rectangular as a base and is desirable to be a flat sectional shape.

(3) Step of sintering the metal particle layer formed by printing on the ceramic substrate under heating to form the heating body 2 on the surface of the ceramic substrate 1.

The metal particle layer formed by printing of the electrically conductive paste is heated and fired to remove the resin and the solvent and sinter the metal particles (the heating-firing temperature is 500~1000°C). In this conn ction, for xampl , wh n a m tal oxide is added to th lectrically

conductive past , the m tal particl s, ceramic plate-shap d body and metal oxide are integrally united by sintering, so that the adhesion property between the heating body and the ceramic plate-shaped body is improved.

(4) Further, a metal covering layer is formed on the surface of the metal particle layer 4, if necessary. This treatment can be carried out by electrolytic plating, electroless plating, sputtering or the like, but the electroless plating is most suitable considering mass production.

(5) Onto an end portion of the pattern of the thus obtained heating body is attached a terminal pin 3 for the connection to a power source through a solder.

B. In case of forming the heating body in the inside of the ceramic substrate (Fig. 3)

(1) Ceramic powder such as nitride ceramic, carbide ceramic or the like is mixed with a binder and a solvent to obtain a green sheet 31.

As the ceramic powder, use mkay be made of aluminum nitride, silicon carbide and the like, and if necessary, a sintering aid such as yttrium oxide (yttria) or the like may be added. As the binder, at least one selected from acrylic binder, ethyl cellulose, butyl cellosolve and polyvinyral is desirable. As the solvent, it is desirable to use one or more sel cted from α-terpineol and glycol.

A paste obtain d by mixing th m is shaped

into a sh t by a doctor blade m thod to produce a gr en sh et 31. In the thus obtained gr n sheet may be formed a through-hole 8 for inserting a support pin 7 for silicon wafer or a recess portion 62 for embedding a thermocouple 61, if necessary. The through-hole 8 or recess portion 62 is formed by punching or the like.

The green sheet has a thickness of about 0.1~5 mm.

(2) Then, a metal particle layer as a heating body is printed on the green sheet.

The metal particle layer 4 as a heating body is formed by printing a metal paste or an electrically conductive paste using an electrically conductive ceramic.

Such a paste contains the metal particles or electrically conductive ceramic particles therein. As the metal particle, tungsten or molybdenum is optimum, and as the electrically conductive ceramic particle, a carbide of tungsten or molybdenum is optimum. Because they are hardly oxidized and are less in the lowering of thermal conductivity.

The tungsten particles or molybdenum particles have an average particle size of 0.1~5 μm. When the size is too large or too small, the printing of the electrically conductive paste is difficult. As the electrically conductive paste, it is optimum to us tungst n past or molybdenum past pr pared by mixing 85~97 parts by weight of the

m tal particle or th electrically conductiv c ramic particle, 1.5-10 parts by weight of at l ast one binder selected from acrylic binder, ethyl cellulose, butyl cellosolve and polyvinyral and 1.5~10 parts by weight of at least one solvent selected from α-terpineol and glycol.

(3) Next, the green sheet 31 printed with the heating body 2 in the step (2) and another green sheet 31 obtained by the same method as in the step (1) are laminated.

In the illustrated embodiment, 37 sheets are laminated on an upper surface of the metal particle layer 4 (heating face side) and 17 sheets are laminated on an opposite side. That is, the forming position of the heating body 2 is made eccentric in a thickness direction by making the number of green sheets (1) laminated on the upper side (heating face side) of the heating body (2) printed green sheet larger than the number of green sheets laminated on the lower side. Desirably, the ratio of upper side to lower side is rendered into 1/1~1/99 by laminating the great number of green sheets having the same thickness. Concretely, 20~50 sheets are laminated on the upper side, and 5~20 sheets are laminated on the lower side.

(4) The green sheets and electrically conductive paste are sintered by heating and pressing. The heating t mperatur is 1000~2000°C, and the pr ssing is carried out at 100~200 kg/cm^2 un

an in rt gas atmosphere. As th in rt gas, us may be mad of argon, nitrogen and th like.

Finally, a solder paste is printed on a portion to be attached with a terminal pin 3, and thereafter a terminal pin 3 is placed and fixed by reflowing under heating. The heating temperature for reflowing the solder paste is preferably 200~500°C. Further, a thermocouple may be embedded, if necessary.

EXAMPLES

(Example 1) Heater made of aluminum nitride ceramic substrate

(1) A mixed composition of 100 parts by weight of aluminum nitride powder (average particle size 1.1 μm), 4 parts by weight of yttria (average particle size 0.4 μm), 12 parts by weight of an acryl binder and alcohol is rendered into granulated powder by a spray drying method.

(2) The granulated powder is placed in a mold and shaped into a flat plate to obtain a green shaped body. The green shaped body is drilled to from a through-hole 8 for inserting a support pin for semiconductor wafer and a recess portion (not shown) for embedding a thermocouple.

(3) The green shaped body is hot pressed at 1800°C under a pressure of 200 kg/cm^2 to obtain an aluminum nitrid plated body having a thickness of 3 mm. It is cut out into a disc having a diam ter of

210 mm to form a ceramic plat d body (c ramic substrate) 1.

(4) An electrically conductive paste is printed on the ceramic substrate 1 obtained in the item (3) by screen printing. The printed pattern is a concentric circle pattern as shown in Fig. 1. As the electrically conductive paste is used Solvest PS 603D, trade name, made by Tokuriki Kagaku Kenkyusho, which is used for the formation of through-hole in a printed wiring board. This electrically conductive paste is a silver/lead paste and contains 7.5 wt% of a metal oxide being a mixture of lead oxide, zinc oxide, silica, boron oxide and alumina (weight ratio of 5/55/10/25/10) per the amount of silver. Moreover, a flake having an average particle size of 4.5 μm is used as silver.

(5) The ceramic substrate printed with the electrically conductive paste is heated and fired at 780°C to sinter silver and lead in the electrically conductive paste and bake the ceramic substrate 1. The pattern of silver-lead sintered body 4 has a thickness of 5 μm, a width of 2.4 mm and an area resistivity of 7.7 mΩ/□.

(6) The ceramic substrate 1 of the item (5) is immersed in an electroless nickel plating bath comprised on an aqueous solution of 80 g/l of nickel sulfate, 24 g/l of sodium hypophosphite, 12 g/l of sodium acetate, 8 g/l of boric acid and 6 g/l of ammonium chloride to pr cipitate a nick l layer

having a thickn ss of 1 μm on the surfac of the silver-lead sintered body 4, whereby a h ating body 2 is formed.

(7) A silver-lead solder paste is printed on a terminal attaching portion for ensuring connection to a power source by screen printing 1 to form a solder layer (made by Tanaka Kinzoku K.K.) 6. Then, a terminal pin 3 of Kovar is placed on the solder layer 6 and reflowing is carried out by heating at 420°C to fix the terminal pin 3 to the surface of the heating body 2.

(8) A thermocouple for temperature control (not shown) is embedded to obtain a heater 100 (Figs. 1 and 2).

(Example 2) Heater of silicon carbide ceramic substrate

The basically same steps as in Example 1 are repeated except that silicon carbide powder having an average particle size of 1.0 μm is used, and the sintering temperature is 1900°C, and the surface is fired at 1500°C for 2 hours to form SiO_2 layer having a thickness of 1 μm on the surface.

(Example 3)

With respect to the heaters of Examples 1 and 2, followability of temperature in the heating face of the ceramic substrate to change of voltage or current and pull strength of the heating body 2 are measur d. That is, when th voltage is appli d to ach heat r, the temp rature change is observ d in

0.5 second in the h ater of Exampl 1, and th t mperature change is obs rved in 2 s conds in the heater of Example 2. On the other hand, the pull strength of the heating body 2 is 3.1 kg/mm^2 in the heater of Example 1 and 3 kg/mm^2 in the heater of Example 2.

(Example 4) Heater provided in its inside with a heating body (Figs. 3, 5)

(1) A mixed composition of 100 parts by weight of aluminum nitride powder (made by Tokuyama Co., Ltd. average particle size 1.1 μm), 4 parts by weight of yttria (average particle size 0.4 μm), 11.5 parts by weight of acryl binder, 0.5 part by weight of a dispersing agent and 53% by weight of a mixed alcohol of 1-butanol and ethanol is shaped with a doctor knife to obtain a green sheet 31 having a thickness of 0.47 mm.

(2) The green sheet 31 is dried at 80°C for 5 hours, and a through-hole for inserting a support pin for semiconductor wafer and a through-hole 38 for the connection between a heating body and a terminal pin having diameters of 1.8 mm, 3.0 mm and 5.0 mm are formed by punching.

(3) An electrically conductive paste A is prepared by mixing 100 parts by weight of tungsten carbide particles having an average particle size of 1 μm, 3.0 parts by weight of acrylic binder, 3.5 parts by weight of α-terpineol and 0.3 part by w ight of a dispersing ag nt.

And also, an electrically conductive past B is prepared by mixing 100 parts by weight of tungsten carbide particles having an average particle size of 3 μm, 1.9 parts by weight of acrylic binder, 3.7 parts by weight of α-terpineol and 0.2 part by weight of a dispersing agent.

The electrically conductive paste A is printed on the green sheet 31 in a pattern form by screen printing. The printed pattern is concentric circles as shown in Fig. 1. And also, the electrically conductive paste B is filled in the through-hole 38 for connecting to the terminal pin.

Further, 37 green sheets 31 not printed with the electrically conductive paste A are laminated on upper side (heating face) and 17 green sheets 31 are laminated on lower side, which are united at 130°C under a pressure of 80 kg/cm^2 to obtain a laminate (Fig. 3).

(4) The laminate is degreased in a nitrogen gas at 600°C for 5 hours and hot pressed at 1890°C under a pressure of 150 kg/cm^2 for 3 hours to obtain an aluminum nitride plate-shaped body having a thickness of 3 mm. It is cut out into a disc having a diameter of 230 mm to provide a ceramic substrate 51 having a heating body of 6 μm in thickness and 10 mm in width therein (Fig. 5(a)).

(5) The ceramic substrate 51 of the item (4) is polished with diamond grindston and a mask is plac d ther on, which is subject d to blast

treatment with glass b ads to form a hole 62 for housing a th rmocouple (Fig. 5(d)).

(6) Further, a part of the surface of the through-hole 38 is enlarged to form a recess portion 48 as shown in Fig. 4, and a gold solder consisting of Ni-Au alloy is supplied to the recess portion 48 and reflowed by heating at 700°C to connect a terminal pin 60 of Kovar (Fig. 5(c)).

Moreover, the connection of the terminal pin 60 is rendered into a three point support utilizing the recess portion 48, which is desirable to ensure the connection reliability of the terminal pin 60.

(7) A plurality of thermocouples 61 for the temperature control are embedded in the hole 62 to obtain a ceramic heater (Fig. 5(d)).

(Comparative Example 1) Heater of aluminum plate

A nickel-chromium wire supported by silicone rubber is used as a heating body and sandwiched between an aluminum plate having a thickness of 15 mm and a support plate and fixed by bolts to form a heater. When a voltage is applied to this heater, 24 seconds is required for the observation of temperature change.

(Comparative Example 2) Alumina heater

The same procedure as in Example 1 is fundamentally repeated except that a composition comprising 100 parts by weight of alumina powder (av rag particle size 1.0 μm), 12 parts by weight of acryl bind r and alcohol is granulated by a spray

drying m thod and placed in a mold and shaped into a flat plate to form a green sheet and then the green sheet is hot pressed at 1200°C under a pressure of 200 kg/cm^2 to obtain an alumina substrate having a thickness of 3 mm.

And also, an electrically conductive paste is prepared by mixing 100 parts by weight of tungsten particles having an average particle size of 3 μm, 1.9 parts by weight of acrylic binder, 3.7 parts by weight of α-terpineol and 0.2 part by weight of dispersing agent and printed. The ceramic substrate printed with the electrically conductive paste is fired by heating at 1000°C to sinter tungsten.

(Example 5)

The same procedure as in Example 4 is fundamentally repeated except that the heating body is not flat but is a square of 20 μm in thickness x 20 μm in width at section (aspect ratio of 1).

(Example 6)

The same procedure as in Example 4 is fundamentally repeated except that the printing conditions are changed and the heating body is not flat but is 5 μm in thickness x 72 mm in width at section (aspect ratio of 12000).

(Example 7)

The same procedure as in Example 4 is fundamentally repeated except that 24 green sheet are laminated on upper sid of the gre n sh t printed with th electrically conductive past and

25 gr n sh ts ar laminat d on lower side thereof and the heating body is located in a c nter of th ceramic substrate.

(Example 8)

The same procedure as in Example 1 is fundamentally repeated except that an electrically conductive paste having the following composition is prepared instead of Solvest PS603D.

Silver powder spherical, average particle size of 5.0 μm, 100 parts by weight

Metal oxide (weight ratio of lead oxide, zinc oxide, silica, boron oxide and alumina of 5/55/10/25/5) 7.5 parts by weight

Area resistivity 4 mΩ/□

(Example 9)

(1) A composition comprising 100 parts by weight of aluminum nitride powder (average particle size 1.1 μm), 4 parts by weight of yttria (yttrium oxide, average particle size 0.4 μm), 12 parts by weight of acryl binder and alcohol is granulated by a spray drying method.

(2) The granulated powder is placed in a mold and shaped into a flat plate to obtain a green sheet. The green sheet is drilled to form a through-hole for inserting a support pin for semiconductor wafer and a bottomed hole for embedding a thermocouple.

(3) The green sheet is hot pressed at 1800°C und r a pressur of 200 kg/cm^2 to obtain an aluminum nitrid substrat having a thickn ss of 3 mm. This

is cut out into a disc having a diameter of 210 mm to provide a c ramic substrate 1.

Further, a metal mask is placed on the ceramic substrate 1 and subjected to a sand blast treatment with alumina powder having a diameter of 1 μm to form a groove having a width of 2.4 mm and a depth of 6 μm at a position for forming a heating body.

(4) An electrically conductive paste is printed on the groove of the ceramic substrate 1 of the step (3) by screen printing to form a metal particle layer. The pattern of the metal particle layer is a concentric circle pattern as shown in Fig. 1. As the electrically conductive paste is used Solvest PS 603D, trade name, made by Tokuriki Kagaku Kenkyusho, which is used for the formation of through-hole in a printed wiring board. This electrically conductive paste is a silver/lead paste and contains 7.5 wt% of a metal oxide being a mixture of lead oxide, zinc oxide, silica, boron oxide and alumina (weight ratio of 5/55/10/25/5) per the amount of silver. Moreover, a flake having an average particle size of 4.5 μm is used as silver.

(5) The ceramic substrate provided with the metal particle layer is fired by heating at 780°C to sinter silver and lead in the metal particle layer (electrically conductive paste) and bake onto the c ramic substrate 1. The pattern of th silver-lead sintered body 4 is 5 μm in thickness, 2.4 mm in

width and 7.7 mΩ/□ in ar a resistivity.

(6) Th ceramic substrat of the item (5) is immersed in an electroless nickel plating bath comprised of an aqueous solution comprising 80 g/l of nickel sulfate, 24 g/l of sodium hypophosphite, 12 g/l of sodium acetate, 8 g/l of boric acid and 6 g/l of ammonium chloride to precipitate a nickel layer 5 having a thickness of 1 μm on the surface of the silver-lead sintered body 4 to thereby form a heating body.

(7) A silver-lead solder paste is printed on a terminal attaching portion for ensuring connection to a power source by screen printing 1 to form a solder layer (made by Tanaka Kinzoku K.K.) 6. Then, a terminal pin of Kovar is placed on the solder layer 6 and reflowing is carried out by heating at 420°C to fix the terminal pin to the surface of the heating body 2 see Fig. 6).

In this example, the heating body is embedded in the inside of the ceramic substrate but is exposed from the surface thereof as shown in Fig. 6(a). And also, the heating body may be partly embedded in the inside of the ceramic substrate and be at a partly exposed state as shown in Fig. 6(b).

In this example, response time, temperature difference and pull strength are measured likewise Examples 1 and 8. The results are shown in Table 1.

(Comparativ Example 3)

The sam procedur as in Exampl 1 is

fundam ntally repeat d exc pt that l ad oxide and zinc oxid are added to Solvest PS603D to adjust th amount of the metal oxide to 10 wt%. The area resistivity of the resulting heating body is 50 mΩ/□.

Moreover, time till the confirmation of temperature change after the application of voltage (response time) is measured with respect to Examples 1 to 8 (other than Example 3) and Comparative Examples 1 to 3. And also, the difference between maximum temperature and minimum temperature of the heating face when the surface temperature is 600°C is measured. Moreover, the pull strength (unit kg/2 mm□) is measured at a zone of 2 mm x 2 mm with respect to Examples 1 and 8.

The results are shown in Table 1.

Table 1

	Response time (second)	Temperature difference (°C)	Pull strength (kg/2mm□)
Example 1	0.5	8	12.4
Example 2	2.0	9	
Example 4	1.0	8	
Example 5	1.6	15	
Example 6	0.8	18	
Example 7	0.7	18	
Example 8	0.7	18	6.0
Example 9	0.8	9	24.0
Comparative Example 1	24	15	
Comparative Exampl 2	40	22	
Comparative Example 3	0.8	15	

Sub B)

INDUSTRIAL APPLICABILITY

As mentioned above, the ceramic heater according to the invention is thin and light and practical and is particularly used for heating and drying semiconductor products in the field of semiconductor industry.

Furthermore, in the ceramic heater according to the invention, the nitride ceramic or carbide ceramic is used as the ceramic substrate and is thinned, so that it is excellent in the temperature followability of heating face against the change of voltage or current and is easy in the temperature control. Moreover, it is excellent in the uniformity of temperature distribution of the heating face and can conduct the efficient drying of the semiconductor product.